Geologic Resource Evaluation Scoping Summary
Bighorn Canyon National Recreation Area

This report highlights a geologic resource evaluation scoping session that was held in Bighorn Canyon National Recreation Area on May 18 and 19, 2005. The NPS Geologic Resources Division (GRD) organized this scoping session in order to view the geologic resources, assess the status of geologic maps and digitizing, and discuss resource management issues and needs and Bighorn Canyon National Recreation Area. During the meeting, participants also discussed map coverage for Little Bighorn Battlefield National Monument. In addition to GRD staff, participants included park staff and cooperators from the Montana Bureau of Mines and Geology, Northwest Wyoming Community College, and Colorado State University (table 1).

Table 1. Scoping Session Participants

Name	Affiliation	Phone	E-mail
Cassity Bromley	Biological Science Technician, Bighorn Canyon National Recreation Area	307-548-5416	cassity_bromley@nps.gov
Tim Connors	Geologist/GRE Program GIS Lead, NPS Geologic Resources Division	303-969-2093	tim_connors@nps.gov
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Katie KellerLynn	Geologist/Senior Research Associate, Colorado State University	970-389-2723	kellerlynn@estesvalley.net
David Lopez	Geologist, Montana Bureau of Mines and Geology	406-657-2632	dlopez@mtech.edu
Carol McCoy	Branch Chief, NPS Geologic Resources Division	303-969-2096	carol_mccoy@nps.gov
Tom Oesleby	Geology Professor, Northwest College	307-754-6054 307-527-6844	tom.oesleby@northwestcollege.edu
Jim Staebler	Park Ranger, Bighorn Canyon National Recreation Area	307-548-5403	james_staebler@nps.gov

Wednesday, May 18, involved a welcome to the national recreation area and an introduction to the Geologic Resource Evaluation (GRE) Program, including status of reports and map products. Discussion focused on map coverage of Bighorn Canyon National Recreation Area, Little Bighorn Battlefield National Monument, and other "quadrangles of interest" in the vicinity. David Lopez (geologist, Montana Bureau of Mines and Geology) and Tom Oseleby (geology professor, Northwest College) presented information about the stratigraphy and structural setting of Bighorn Canyon National Recreation Area. In addition, the group discussed geologic issues of concern for park managers.

Thursday, May 17, involved a field trip led by David Lopez and Tom Oesleby. The selected stops highlighted the recreation area's stratigraphy and current resource management issues.

Stratigraphic and Structural Setting of Bighorn Canyon National Recreation Area

The most prominent rocks in Bighorn Canyon National Recreation Area are the Mississippian-age Madison Group, the Triassic-age Chugwater Formation, and Cambrian-Devonian limestone and shale exposed in the western front of the Bighorn Mountains (fig. 1). The regional setting lies within the province of Laramide basins and uplifts. The Laramide mountain-building event began in latest

Cretaceous Period (~70 million years ago) and ended in the Paleocene Epoch. Uplift along reverse faults that flatten with depth characterizes the mountains. The national recreation area is at the northern end of the Bighorn Basin between the Pryor and Bighorn uplifts.

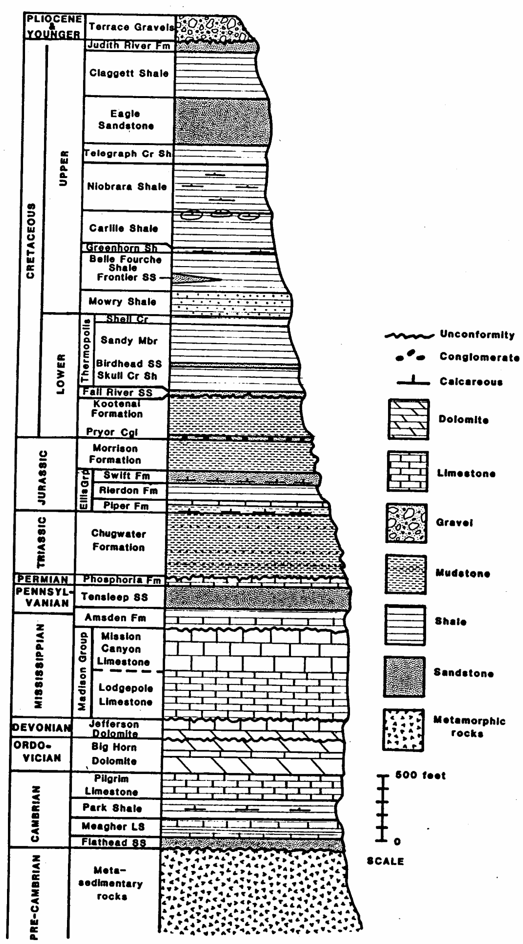

Figure 1. Stratigraphic section that includes prominent rocks in Bighorn Canyon National Recreation Area.

Overview of Geologic Resource Evaluation Program

The GRE Program is a collaborative effort between the NPS Geologic Resources Division and the NPS Inventory and Monitoring (I&M) Program with assistance from the US Geological Survey (USGS), state geological surveys, and numerous individual volunteers and cooperators at colleges, universities, and National Park System units. The Geologic Resources Division administers the Abandoned Mine Lands (AML) and Geoscientists-in-the-Parks (GIP) Programs, which also contribute to the inventory. Director's Order 77 (NPS 75) defines geology as one of 11 baseline inventories useful for resource management: geology, species lists, bibliographies, base cartography, vegetation, water quality, soils, species surveys, species distribution (vascular plants and vertebrates), air quality, and climatic data. A major goal of the collaborative effort is to provide a broad baseline of geologic data and assist park managers with issues that may arise.

The objectives of the geologic resource evaluation scoping meetings are as follows:

1. To identify geologic mapping coverage and needs

2. To identify distinctive geologic processes and features
3. To identify resource management issues
4. To identify potential monitoring and research needs

Outcomes of the scoping process include the following items:

1. A scoping summary (this document)
2. A bibliography
3. A digital geologic map
4. A geologic resource evaluation report

The scoping process includes a site visit with local experts, evaluation of the adequacy of existing maps, and discussion of park-specific geologic management issues. The emphasis of scoping is not to routinely initiate new geologic mapping projects but to aggregate existing information and identify where serious geologic data needs and issues exist in the National Park System.

Status of Scoping and Products

As of February 2006, the NPS Geologic Resources Division had completed the scoping process for 154 of 272 "natural resource" parks. Staff and partners of the GRE Program have completed digital maps for 65 parks. These compiled geologic maps are available for downloading from the NR-GIS Metadata and Data Store at http://science.nature.nps.gov/nrdata. The US Geological Survey, various state geological surveys, and investigators at academic institutions are in the process of preparing mapping products for 42 parks. Bibliographies for 272 parks are currently undergoing data validation and updates. Writers have completed 15 GRE reports with 54 in progress.

Geologic Maps for Bighorn Canyon National Recreation Area

During the scoping session on May 18 and 19, 2005, Tim Connors (GRD) presented a demonstration of some of the main features of the digital geologic map model used by the Geologic Resource Evaluation Program. The model reproduces all aspects of a paper map, including notes, legend, and cross sections, with the added benefit of being GIS compatible. The map product is digitized using ESRI ArcView/ArcInfo format with shape files and other features, including a built-in help file system to identify the map units. The cross-section lines (e.g., A–A') are subsequently digitized as a shape file and are hyperlinked to the scanned images.

All units in the National Park System have "quadrangles of interests" mapped at one or more of the following scales: 7.5' × 7.5' (1:24,000), 15' × 15' (1:62,500), or 30' × 60' (1:100,000). For the purpose of geologic resource evaluations, GRE staff would like to obtain digital geologic maps of all identified 7.5-minute (1:24,000-scale) quadrangles of interest for a particular park. The geologic features mapped at this scale are equivalent to the width of a one-lane road. Often for simplicity, geologic map makers compile 30-minute × 60-minute (1:100,000-scale) maps, which provide greater consistency and cover more area. The quadrangles of interest for Bighorn Canyon and Little Bighorn Battlefield are shown in figure 2. The contents of this document reflect what participants know about the published geologic maps as of February 2006.

Map coverage for Bighorn Canyon National Recreation Area consists of 20 quadrangles of interest (1:24,000 scale): Lemonade Springs, Mountain Pocket Creek, Yellowtail Dam, Grapevine Dome, Bear Coulee SW, Peyote Point, Little Finger Ridge, Dead Indian Hill (Montana), East Pryor Mountain, Big Ice Cave, Two Point, Hillsboro (Montana), Mystery Cave, Simmons Canyon, Natural Trap Cave, Sykes Spring, Cottonwood Canyon (Wyoming), Kane (Wyoming), Lovell Lakes, Lovell (Wyoming), which are situated on the Lodge Grass, Bridger, Burgess Junction, and Powell 30' × 60' sheets (see figure 2).

GRE staff will derive the digital geologic data of these quadrangles from the following sources. “GMAP” identification numbers are part of the GRE Program database.

Hallberg, L.L., Case, J.C., Jessen, C.A., and Kirkaldie, A.L., 1999, Preliminary digital surficial geologic map of the Powell 30 minute × 60 minute quadrangle, Big Horn and Park Counties, Wyoming and southern Montana: Wyoming State Geological Survey Geologic Hazards Section Digital Map 99-3, scale 1:100,000 (GMAP 5915).

Hallberg, L.L., Case, J.C., and Noecker, B.L., 2001, Preliminary digital surficial geologic map of the Burgess Junction 30 minute × 60 minute quadrangle, Sheridan, Big Horn, and Johnson Counties, Wyoming and southern Montana: Wyoming State Geological Survey Geologic Hazards Section Digital Map 01-2, scale 1:100,000 (GMAP 5914).

Lopez, D.A., 2000, Geologic map of the Bridger 30’ × 60’ quadrangle, Montana: Montana Bureau of Mines and Geology Geologic Map 58, scale 1:100,000 (GMAP 3941).

Vuke, S.M., Wilde, E.M., Lopez, D.A., and Bergantino, R.N., 2000, Geologic map of the Lodge Grass 30’ × 60’ quadrangle, Montana: Montana Bureau of Mines and Geology Geologic Map 56, scale 1:100,000 (GMAP 2732).

On February 2, 2006, GRE staff acquired the digital files for the Lodge Grass and Bridger 30’ × 60’ sheets from the Montana Bureau of Mines and Geology at ftp://sun2.mtech.edu/pub/geology. The contact for this information is Ken Sandou in the Butte office of the Montana Bureau of Mines and Geology. He can be reached at 406-496-4151. GRE staff will need to convert these data to the GRE model. These maps include both bedrock and surficial deposits and are adequate for park resource management.

On February 13, 2006, GRE staff acquired the digital files for both the Burgess Junction and Powell 1:100,000-scale surficial maps from the Wyoming Geological Survey (WGS) (Contacts: Allory Diss, GIS manager, and Phyllis Ranz, GIS specialist). Additionally, WGS staff provided (posted to the NPS ftp site) statewide bedrock geology at 1:500,000 scale. GRE staff analyzed these digital files and determined that the information is probably adequate for the bedrock coverage for these two sheets.

Geologic Maps for Little Bighorn Battlefield National Monument

In addition to discussing the status of digital geologic maps for Bighorn Canyon National Recreation Area, participants discussed map coverage for Little Bighorn Battlefield National Monument, which is located northeast of the national recreation area. Map coverage for Little Bighorn Battlefield National Monument consists of four quadrangles of interest (1:24,000 scale): Crow Agency SE, Crow Agency, Lodge Grass NE, and Benteen, which are situated on the Hardin and Lodge Grass 30’ × 60’ sheets (figure 2). The Crow Agency SE and Crow Agency quadrangles are situated on the Hardin 30’ × 60’ sheet; the Lodge Grass NE and Bantheen quadrangles are situated on the Lodge Grass 30’ × 60’ sheet.

GRE staff will derive the digital geologic data of these quadrangles from the following sources:

Vuke, S.M., Wilde, E.M., and Bergantino, R.N., 1999, Geologic map of the Hardin 30’ × 60’ quadrangle, eastern Montana [revised 1999]: Montana Bureau of Mines and Geology Open-File Report MBMG-392, scale 1:100,000 (GMAP 5937).

Vuke, S.M., Wilde, E.M., Lopez, D.A., and Bergantino, R.N., 2000, Geologic map of the Lodge Grass 30’ × 60’ quadrangle, Montana: Montana Bureau of Mines and Geology Geologic Map 56, scale 1:100,000 (GMAP 2732).

On February 2, 2006, Tim Connors acquired the digital files for the Lodge Grass and Hardin 30’ × 60’ sheets from the Montana Bureau of Mines and Geology at ftp://sun2.mtech.edu/pub/geology. The contact for this information is Ken Sandou in the Butte office of the Montana Bureau of Mines and Geology. He can be reached at 406-496-4151. GRE staff will need to convert these data to the GRE model. These maps are adequate for coverage of both bedrock and surficial deposits.

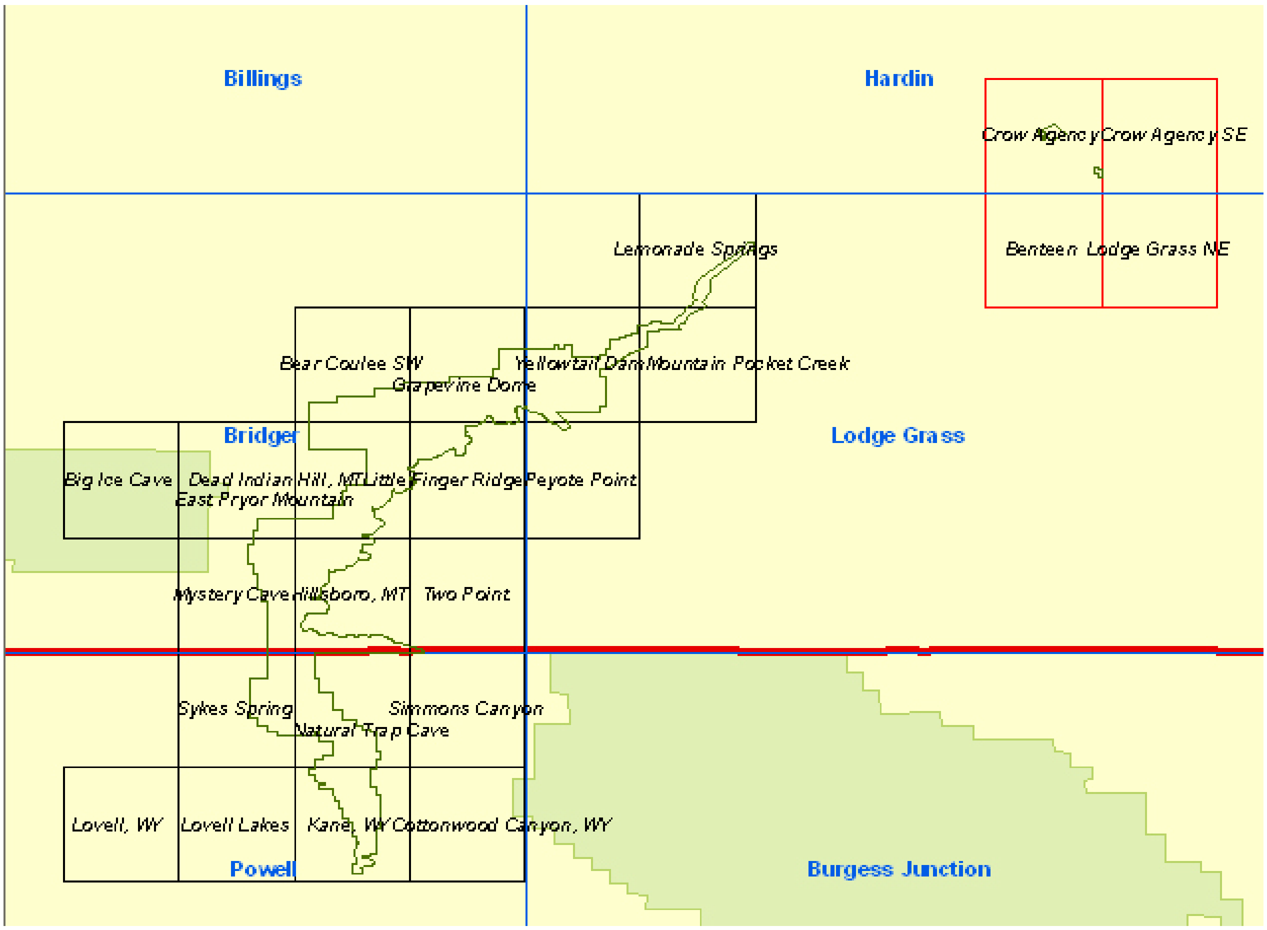

Figure 2. Quadrangles of interest for Bighorn Canyon National Recreation Area and Little Bighorn Battlefield National Monument. Names in black indicate 7.5-minute quadrangles (1:24,000 scale); names in blue indicate 30-minute × 60-minute quadrangles (1:100,000 scale). The red line represents the Wyoming-Montana state line. Green outlines indicate the boundaries of the recreation area and the monument.

Geologic Resource Evaluation Report

Typically GRE reports include sections about geologic management issues, geologic features and processes, the park’s geologic history, a map unit properties table that highlights the significant features and resource concerns of each map unit in the park, references (different from the bibliography), and various appendices (e.g., map graphics and scoping report). During the May 18 meeting, GRD staff showed examples of completed GRE reports. Participants deemed such a report to provide useful information for making resource-management decisions and preparing interpretive materials.

Geologic Features, Processes, and Issues in Bighorn Canyon National Recreation Area

The scoping session at Bighorn Canyon provided the opportunity to capture a rough outline of particular geologic features and processes operating in the national recreation area, which may be of concern for resource managers. This information will serve as data for the preparation of the final GRE report. Park staff determined that the "top" issues related to geology are (1) sedimentation/siltation (filling up the reservoir) and (2) interpretation of the geology of the canyon.

Sedimentation/Siltation

On October 15, 1966, following the construction of the Yellowtail Dam by the Bureau of Reclamation, an act of Congress established Bighorn Canyon National Recreation Area. Yellowtail Dam harnessed the waters of the Bighorn River and turned this variable stream into a lake. Bighorn Lake extends approximately 60 miles (97 km) through Wyoming and Montana, 55 miles (88 km) which are held within Bighorn Canyon. The creation of the dam provided hydro-electric power, some irrigation waters, and many opportunities for recreation. The recreation area is composed of more than 120,000 acres (48,564 ha), 68,490 acres (27,717 ha) of which are federal. The recreation area straddles the Wyoming-Montana border.

The top resource management issue at Bighorn Canyon National Recreation Area is sedimentation (siltation). Silt and sand that is suspended throughout Bighorn Lake ultimately accumulates, in particular as stream-deposited silt behind the dam. The primary concern is that the reservoir will fill in over time. In 1994 the Natural Resource Conservation Service estimated the Bighorn River dumped approximately 4,000 tons (3,600 metric tons) of silt a day into the southern end of Bighorn Lake. This has resulted in the deposition of some 50 feet (15 m) of silt into the Horseshoe Bend area since the dam began functioning in 1968. This deposition is expected to continue until the silt reaches an elevation of 3,620 feet at which time managers estimate that a state of equilibrium will be reached and the incoming silt will be carried farther down the reservoir. Park managers expect that siltation will reach "elevation 3,620" sometime around 2006, though siltation tends to be episodic and no exact date can be established.

The infrastructure of the recreation area includes two marinas: Ok-A-Beh and Horseshoe Bend. In addition, Three Mile Access, Afterbay Dam, and Barry's Landing host boat ramps. Sedimentation, compounded by the recent drought in the region, has resulted in the closure of the marina at Horseshoe Bend. Park staff suspect that the marina will be moved to Barry's Landing; however, this location has no marina facilities. If the drought does not subside, returning the reservoir return to "full pool," reopening Horseshoe Bend would require dredging. The drought also has affected the use of boat ramps at the park. In 2005 the lake was at full pool, and Horseshoe bend was open. Precipitation levels indicate that the lake will be at full pool again in 2006 (Cassity Bromley, written communication, 23 February 2006). However, over the long term, drought and sedimentation are still issues for park management.

The significant sedimentation occurring in Bighorn Lake causes aggradation and the formation of point bars, which encourages growth of tamarisk, an invasive species. Hence, sedimentation is a management concern for biologic as well geologic reasons. In addition, since the creation of the dam, mass wasting periodically occurs alongside the lake, which adds to the sediment supply. In the Bull Elk Basin, frequent slumping has resulted in the formation of a minor scarp around the basin. Camping in the basin is now prohibited because of slumping. However, because camping locations are limited and slumping appears to have decreased, park management is considering reopening Bull Elk Basin for camping.

With two reservoirs upstream of Yellowtail Dam, flooding is of low management concern as these two dams should control flood potential. Moreover, the Bureau of Reclamation closely monitors water in the Bighorn River. Smaller drainages in the park, however, have the potential for flash flooding, but this too is of low management concern at present.

Participants also discussed the following features and processes:

Caves and Karst

An extensive network of known caves occurs within Bighorn Canyon National Recreation Area. Potential for additional caves exists anywhere in the Madison Formation. In the past, investigators have inventoried many of the caves that occur in Bighorn National Recreation Area. Two books, *Caves of Montana* and *Caves of Wyoming*, include reproductions of cave maps. However, based on the length of Bighorn Cavern, the largest cave in the national recreation area, these other caves have the potential for having greater lengths than their inventories show. In addition, ice caves—similar to Big Ice Cave, which is located outside the recreation area in the Pryor Mountains—may exist within Bighorn Canyon National Recreation Area.

Bighorn Cavern is located on Crow tribal land; however, not many Crows use the cave. The National Park Service provides access to the caving public through verbal agreement with the tribe. In general, public use of the cave is minimal, which has resulted in low management concern at the present time. A locked gate covers the cave entrance. Park staff provides cavers with a key when they sign up for a reservation to access the cave. Cavers must rappel into the cave. Park staff does not check cavers' skills before entry; however, at least one member of the party must have some prior experience in the cave.

Though Bighorn Cavern is used infrequently, it is a significant park resource. The cave houses exceptional mineral crystals. Park staff has set up photo points to monitor theft and damage. Park staff is confident that the good relationship between park staff and many of the cavers would result in reports of any damage.

Karst resources in Bighorn National Recreation Area are both modern and ancient. An investigator from the Denver Museum of Nature and Science completed a PhD thesis on paleokarst in the park. The floors of caves are covered with rockfall, which may be a paleontological resource comparable to Natural Trap Cave in Wyoming. Other possible research that could be conducted in Bighorn Canyon National Recreation Area is paleoclimate studies from speleothems.

Distinctive Geologic Resources

Bighorn Canyon National Recreation Area is a lesser known treasure in the National Park System waiting to be discovered. The canyon itself is an incised meandering stream, which reflects rejuvenation of uplift in the area. A classic abandoned meander occurs within the recreation area and is distinctive because most entrenched rivers in the West do not show such features.

The oil industry separated the Madison Group into units A–D for explanatory purposes (see reference below).

Richards, P.W., 1955, Geology of the Bighorn Canyon-Hardin area, Montana and Wyoming: US Geological Survey Bulletin 1026, 93 p.

Each of these units can be easily seen in the canyon walls. Because of its accessibility, the stratigraphic sequence that is exposed in the national recreation area is a significant interpretive resource. For instance, bighorn sheep like to lamb on particular shelves and ledges of the Madison Group (A, B, C, D)—a biological-geological connection.

Dry Head Agate (Phosphoria Formation) is quarried in the vicinity of Bighorn Canyon National Recreation Area. This agate may be present within the boundaries of the recreation area. Dry Head Agate is appealing to "rockhounds," and though not a concern at present, collecting may become a resource-protection issue as visitation increases in the future.

Disturbed Lands

In the 1950s, extensive exploration for uranium occurred in what is now Bighorn Canyon National Recreation Area. Prospectors excavated and left more than 350 exploration pits and mound structures. In many areas, these abandoned mine lands were a significant disturbance in otherwise nearly pristine desert and steppe landscapes. Because natural reclamation proceeds very slowly in the arid environment, a series of projects was developed to re-contour these sites and plant them with native seed. An environmental assessment (EA) was prepared in 2002–2003 to assess possible adverse effects of reclamation, especially in areas where heavy equipment was necessary, and to provide an opportunity for the public to comment on the proposed reclamation program. Concerns identified during scoping and evaluated in the EA included soils, biotic communities, threatened and endangered species, archaeological resources, visual resources and topography, and visitor use and experience. The preferred alternative is reclamation of the abandoned uranium exploration sites by a combination of re-contouring and seeding with native seed (Alternative B) (http://www.nps.gov/bica/FONZI.pdf).

Eolian Processes

Eolian (windblown) deposits consist primarily of volcanic ash in Bighorn Canyon National Recreation Area. Some of these deposits are as thick as 100 feet (30 m) and have been mined for glass in the past. The deposits have been blown up against the mountain front, east of the park. Geology field trips access the deposits through the recreation area. Ongoing eolian processes are not a concern for park managers; for instance, dust storms are not really a problem. Research by Marith Reheis (e.g., Reheis, 1987) may be useful for an understanding of eolian deposits at the recreation area.

Reheis, M.C., 1987, Gypsic soils on the Kane alluvial fans, Big Horn County, Wyoming: U.S. Geological Survey Bulletin 1590-C, p. C1–C39.

Paleontological Resources

An NPS investigator, Allison Koch, conducted a preliminary inventory of paleontological resources in Bighorn Canyon National Recreation Area. A section about the resources at Bighorn Canyon appears in the following publication, which includes other references of interest:

Koch, A.L., and Santucci, V.L., 2003, Paleontological resource inventory and monitoring—Greater Yellowstone Network: National Park Service, TIC #D-1025, 25 p.

In addition, recent research (e.g., Mickelson [2005], Harris and Lacovara [2004]) indicates that fossil footprints/tracks are a significant paleontological resource at Bighorn Canyon National Recreation Area.

Mickelson, D.L., 2005, Subaqueus tetrapod swim tracks from the Middle Jurassic—Bighorn Canyon National Recreation Area (BCNRA), Wyoming U.S.A.: Geological Society of America Abstracts with Programs, vol. 37, no. 7, p. 440.

Harris, J.D., and Lacovara, K.J., 2004, Enigmatic fossil footprints from the Sundance Formation (Upper Jurassic) of Bighorn Canyon National Recreation Area, Wyoming: Ichnos vol. 11, p. 151–166.

Furthermore, investigators have studied the Morrison Formation in Bighorn Canyon National Recreation Area (e.g., Turner and Peterson, 2004).

Turner, C.E., and Peterson, F., 2004, Reconstruction of the extinct ecosystem of the Upper Jurassic Morrison Formation: Sedimentary Geology, vol. 167, no. 3–4, p. 111–360.

In addition, the potential for Pleistocene-age fossils in Bighorn Cavern in the national recreation area is high. The cave has a sinkhole-type entrance with a debris pile that could produce such resources, although in 2001 none had been found yet (Jason Kenworthy, written communication, 9 March 2006). This assumed potential for Pleistocene fossils is based on Natural Trap Cave, a karst sinkhole feature located on BLM land on the western slope of the Bighorn Mountains just outside Bighorn Canyon National Recreation Area. A debris pile, similar to the one in Bighorn Cavern, occurs at the entrance of Natural Trap Cave, which was excavated and surveyed. Between 1974 and 1980, investigators collected the remains of Pleistocene horses, antelope, sheep, mammoth/mastodons, lemmings, American lions, and American cheetahs. The fossil remains range in age from 11,000 to 20,000 years ago. The cave fauna represents the longest and most extensive continuous record of late Pleistocene biota in the Northern Rocky Mountains (Gilbert and Martin, 1984).

Gilbert, B.M., and Martin, L.D., 1984, Late Pleistocene fossils of Natural Trap Cave, Wyoming, and the climatic model of extinction, *in* Martin, P.S., and Klein, R.G., eds., Quaternary extinctions—A prehistoric revolution: Tucson, The University of Arizona Press, p. 138–147.

Park management set a strategic goal to protect paleontological resources at least until more is known about the size, extent, and condition of these resources. For instance, a site outside of Horseshoe Bend is well known and may provide collecting opportunities. Unfortunately neither staff nor funding is available at this time to achieve the goal (Bighorn Canyon National Recreation Area, five-year strategic plan, 2001–2005, at http://data2.itc.nps.gov/parks/bica/ppdocuments/BICA%2000%20Strategic%20Plan.pdf).

Additional [potential] paleontological resources in Bighorn Canyon National Recreation Area include the following:

- Bison skull (Pleistocene) by causeway (Contact: Marith Reheis at mreheis@usgs.gov, 303-236-1270)
- Belemnites in Sundance Formation (Jurassic)
- Crinoids in Sundance Formation (Jurassic)
- Potential fish fossils in Sundance Formation (Jurassic)
- Dinosaur tracks and bones in Morrison Formation (Jurassic)
- Brachiopods, corals, and spirofirs in the Madison Group (Jurassic)

Wetlands

Wetlands in Bighorn Canyon National Recreation Area are managed cooperatively with the Wyoming Game and Fish Department. In particular, a significant riparian area composed of a complex of managed ponds occurs in the Yellowtail Wildlife Habitat Management Area (southern end of Bighorn Canyon National Recreation Area). Approximately 11,600 acres (4,700 ha) of yellowtail wildlife habitat occur within the boundary of the recreation area. Under the cooperative agreement establishing the recreation area, the Wyoming Game and Fish Department has the primary responsibility for the management of the land within the wildlife habitat. The National Park Service retains the underlying responsibility for the protection of those lands within the habitat area. Over the years cooperation between the two agencies has ranged from very good to excellent. Budget constraints, staff reductions, and reorganization over the last 10 years has forced the Wyoming Game and Fish Department to reduce staffing levels on the habitat area; to date, because of staff dedication and management commitment, this has not had a detrimental effect on the habitat area (Bighorn Canyon National Recreation Area, five-year strategic plan, 2001–2005, at http://data2.itc.nps.gov/parks/bica/ppdocuments/BICA%2000%20Strategic%20Plan.pdf).